A Reciprocal Terrestrial Backhaul Architecture for the Integration of 5G in HTS Networks

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***Abstract*—In this paper, we propose a reciprocal architecture to integrate satellite-based ground gateways with 5G eNodeBs capable of transmitting Terabit/s of data throughput in remote locations. Taking into consideration the need for heterogeneous and reliable satellite terrestrial communication, we propose a gateway connection for backhauling traffic through terrestrial base stations. These satellite gateway feeder links will significantly improve overall throughput by utilizing feeder links in parallel with minimal ground network topology alternations. The proposed solution will provide real-time services to LEO, MEO & GEO satellites in connection with 5G-enabled eNodeBs. This will include managed broadband services, gateway services, monitoring, tracking and control services in a terrestrial backhaul connection fashion.**

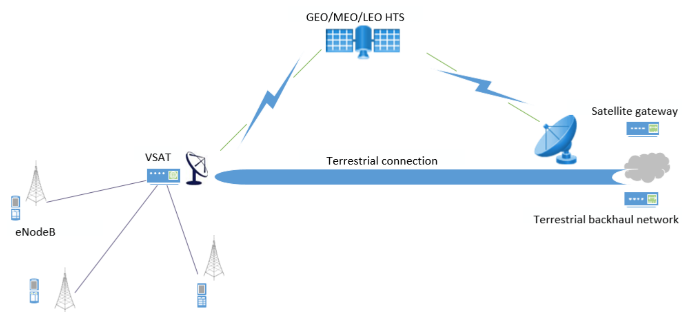

Fig. 1. High Throughput Satellite Network with Feeder Links to eNodeBs

I. Introduction

Over recent years, satellite communications has been a valuable asset to supplement wireless terrestrial networks. It has been shown that geostationary satellites can efficiently cover regions in different parts of the world where terrestrial communication has not been widely accessible. One of the challenges for these satellite networks is the adaptability and adjustment to the technological achievements in the 5G network. Numerous studies have been proposed for overall architecture design of 5G network and satellite systems separately. In this study, we will be proposing a reciprocal architecture design for satellite system which incorporates high throughput links between satellite gateways and feeder links of microwave backhauls [5]-[6].

Using a geostationary reciprocal satellite link with user links in Ku-band or Ka-band can allow higher data throughput in the overall backhaul link of a terrestrial wireless link. For regions where terrestrial backhaul is hard to reach or the costs are much higher in terms of the population coverage, satellites can come into play and complement the overall communication cycle. As an example, a geostationary satellite using a Ku-band frequency can target a range of up to approximately 600 miles and provide Terabit/s of data which can serve one million customers with 40 Mbps of average speeds at a user activity of 25 mErl.

In recent years, 3GPP has advocated for non-terrestrial solutions in radio access networks in particular. Many studies have been proposed for the integration of satellite communication and 5G technologies in hybrid constellations [1]-[3]. This study focuses on a few of the challenges facing this communications link, including propagation delays and Doppler shift. We will provide an overview of the performance and quality of service for a heterogeneous network for both user and feeder link.

The challenge on the user link side in High Throughput Satellite (HTS) is the frequency re-use through the spot beams and on the gateway end is the optical feeder links which will be addressed. As seen in figure 1, an HTS system with optical feeder links can be taken into consideration where it is connected through terrestrial network via the gateway. Based on 5G spectrum public policy position, the main three usage scenarios for 5G to be addressed are the following:

1) ultra-reliable communications, which includes extreme low latency & highly available, secure and reliable means of communications.
2) improved mobile broadband, consisting of multi-gigabit throughputs for upholding massive data traffic growth.
3) Supporting massive machine to machine communications to fully integrate and support a massive number of cheap IoT connections which have improved battrey life and a broader coverage indoors.

II. System Overview

The proposed solution should support extremely high data rates for advanced mobile broadband. LEO and MEO

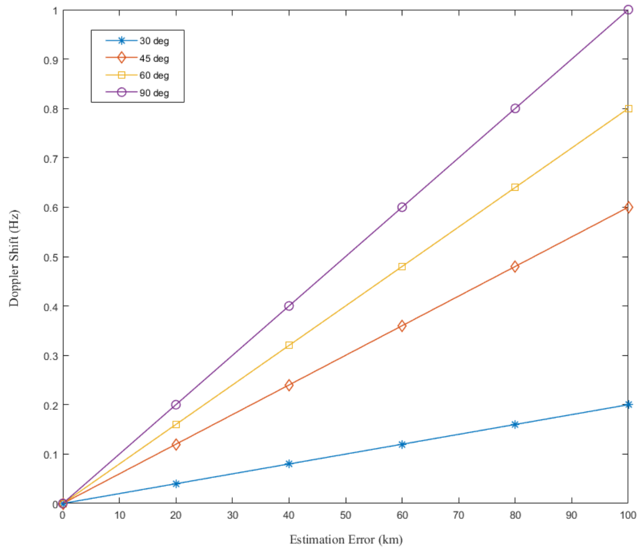

Fig. 2. Doppler shift vs. Estimation Error with different Elevation angles

satellites can easily deliver on this promise were they provide UHD content broadcasting with High Efficiency Video Coding (HEVC) standards which offers improved compression rates. Recent advances in MEO and LEO networks are supporting very latency sensitive applications where they can support 5G networks to comply with the below 1ms latency requirements and delivering content to mobile base stations. Another feature that satellites support is global asset tracking applications which can easily scale M2M communications. One of the advancements of this technique is investment in low cost, phased array satellite transceivers for deploying a feasible IoT solution.

The proposed solution provides backhaul connection to several satellite-based ground networks. The User Equipments (UE) on every cellular beams on the ground will be interconnected via a terrestrial 5G link. The LEO (MEO) constellation gateway will be back connected to the satellite via a feeder which this will provide access to the 5G core network. In this scenario the satellite units are considered reflectors or relay nodes in the sky [4]. The ground terrestrial nodes can be assumed as the evolution of LTE eNodeBs for simplicity. These terrestrial nodes assume the same air interface between the satellite nodes similar to relay nodes and gateways which terminates with the radio protocols. In the proposed system, the relay nodes are reciprocal and coordinated between system gateways which connects to the 5G core network. The terrestrial access link would not need any major alternations and therefore it's easy to deploy with minimal cost. The impact of Doppler shifts and delays will be evaluated in the satellite gateway air interface.

Using a reciprocal hybrid gateway we can see the Doppler shift as a function to different satellite elevation angles shown in figure 2. In this method, the Doppler shift can be mitigated at the user gateway by using a 5G relay node which is equipped with Global Navigation Satellite System that provides autonomous geo-spatial location position throughout the globe.

III. Conclusion

Four major use cases for integrating satellite solutions in 5G can be summarized as : backhauling the eNodeBs, mobile communication on demand, trnking for terrestrial feeds and a hybrid multi-purpose solution. We have studied a reciprocal 5G architecture for a backhaul connection of a satellite link through a 5G terrestrial network, based on the most up to dated 3GPP specifications. In addition, we have studied the significance of Doppler shift in satellite gateway air interface.

References

[1] D. Giggenbach, E. Lutz, R. Mata-Calvo, C. Fuchs and J. Poliak, "A High Throughput Satellite System for Serving whole Europe with Fast Internet Service, Emplyeeing Optical Feeder Links", *Breitbandversorgung in Deutschland*, ISBN 978-3-8007-3925-7, April 2015.

[2] G. Araniti, M. Condoluci, A. Orsino, A. Iera and A. Molinaro *Effective Resource Allocation in 5G-Satellite Networks*. Satellite and Space Communications, IEEE ICC 2015 SAC.

[3] A. Guidotti, A. Vanelli-Coralli, O. Kodheli, G. Colavolpe and T. Foggi"Integration of 5G technologies in LEO Mega Constellations", IEEE 5G Tech Focus, ISBN 978-1-5090-5019-2.

[4] G. Eason, B. Noble, and I. N. Sneddon, "LTE Adaptation for Mobile Broadband Satellite Networks", EURASIP Journal on WirelessCommunications and Networking, Nov. 2009

[5] 3GPP RP-171453 TR 38.811 V0.1.1, "Study on New Radio to Support Non Terrestrial Networks (Release 15)", June 2016.

[6] "Broadband Access via Integrated Terrestrial and Satellite Systems", *ICT-2011.1.1 BATS D4.1: Satellite Network Mission Requirements*, European Project, technical report 2013.

[7] E. Lutz, M. Werner, A. Jahn "Satellite Systems for Personal and Broadband Communications", *Springer, 2000*, www.books.google.com